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TREE STUMP MANIPULATION

An experimental method to accelerate decomposition in tree stumps to compensate for the shortfall in dead wood substrate.

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ABSTRACT

Current forestry exploits put a lot of strain on the global ecosystem that all life on earth depends on. Boreal natural dynamic forest environments are turned into sterile clear-cut areas. Forestry exploits also affect the biodiversity by extracting substantial amounts of dead wood substrate. The natural dynamic forest environment cannot keep up the pace to provide the natural cycle with provisioning these natural dynamic environments with dead wood substrate. The goal to become carbon neutral by 2050 makes the extraction of all wood for energy purposes from the forest obsolete. This includes stumps as well. This study aims to determine if the experimental method of stump manipulation can accelerate stump decomposition to create dead wood substrate from tree stumps to avoid the implementation of heavy stump extracting machines which in turn should be beneficial for the forest ecosystem and increase biodiversity. To test the hypothesis if the stump manipulation method actually works, a basic inventory of decay depth on stumps has been made in a forest environment where the owner implements the tree stump manipulation method. The gathered samples have been analyzed by using a basic T-Test. The results presented no hard results that proved that the tree stump manipulation worked. However, there appeared to be indications in the results of decay where further research might provide better results might provide better results if further research is done. Nonetheless, the results also indicated that stumps created by manual felling have a higher number of insects in them compared to stumps that have been mechanically created. With this result in mind, manually manipulating stumps to mimic natural disturbances can be an interesting forestry measure to consider implementing to boost the restoration of exploited forest areas.

Keywords: stumps, dead wood, extraction, biodiversity, natural disturbances, mimicking, manipulation

Preface

With this thesis I conclude my studies for my Bachelor of Science in Conservation, with a major in Garden and Landscape Crafts at the University of Gothenburg, Sweden.

During my professional experience and as a student in nature conservation, I have been confronted with many occasions where sustainability in nature management is still missing. As a passionate nature enthusiast, I have had the opportunity to come across talented nature enthusiasts who also have encountered many of those occasions where sustainability falls short but approached these shortfalls with interesting solutions. Researching stumps and dead wood and their function in the forest ecosystems for my graduating thesis, has widened my views, and confirmed much of my assumptions, and to be able to put them in words. I want to thank my mentor Eva Gustavsson for her patience, support, and creative ideas during these last three years at the University of Gothenburg. I also want to thank dr Jonas Webjörn for his support, scientific perspectives, imagination, and for the use of his forests as a laboratory.

Contents

1. INTRODUCTION

Forests are undeniably one of the most important motors in the global ecosystem that drives the survival of all species in existence on earth. Forests provide oxygen through photosynthesis, food, and a shelter to countless of organisms that have evolved over thousands of years within these natural dynamic environments (Cohen 2017:52). That in relation to our short modern existence, where extensive forestry damages these natural dynamic environments. Since the 1950's we have been exploiting these natural dynamic environments on a large scale, up to a point where the ecosystem has become stressed and is moving closer to a tipping point (Reyer 2015:12). On the Fennoscandian peninsula we have transformed much of the natural boreal forests into productive tree stands to meet our continuous consumptive demands (Protect the Forest, Sweden & Greenpeace Nordic 2021).

Continuous forests have become fragmented where large patches of these forests are scraped away and turned into monocultural plantations. Forest continuity, where forests continue to grow undisturbed without being affected by forest exploitation, agricultural or other human intervention, has become a rare phenomenon. Breaks in forest continuity have caused a substantial loss in species richness in the past and still continues to do so (Graae 2000:720). Most boreal forests have become monocultural tree stands of the same tree species and consist of same age trees because they have been planted at a same point in time. As our consumption increases so does the extraction for resources from these forest environments. The extraction of forest resources does not just stop at timber, also stumps and other forestry residue, small and coarse, are now being extracted on a large scale where soil scarification and stump extraction methods destroy most of a once perfectly functioning ecosystem and its indisputably important ecosystem services. All this to prepare for a planted forest that will be harvested to meet our consumption and new energy demands to solve our global climate crisis (Ranius et al. 2018:421).

Natural forests encompass a variety of different species of trees and other plants depending on the continuous cycle of interaction, successions and natural disturbances that create new possibilities. Forest environments with natural ecosystem processes contain mixed species of new growth and old growth. Some trees, for instance Scots pine *(Pinus sylvestris)* can be 650 years old, if not older. Whereas in production forests stands of Scots pine, the rotation time is about 80 – 150 years (Naturhistoriska Riksmuseet 2021; Skogssverige 2021). Natural dynamic forest environments also contain a vast amount of new and old dead wood, standing or decomposing on the forest floor, in all the different stages of decay. There is an endless creation of dead wood. This continuous circular process, regulated by an ecosystem, provides dead wood that contributes to an enormous amount of habitat spaces and nourishment in these natural dynamic environments for many species within the flora and fauna realm, such as fungi, lichens, invertebrates, birds, and small mammals (Thorn et al. 2020:507). Because of the overexploitation of these natural dynamic environments for resources, we are taking away a pristine natural dynamic environment and replace it with monocultures. When forests lose their diversity, many species are pushed to the brink of extinction.

1.1.1. Importance of dead wood

In a natural forest, the general amount of dead wood makes up for about 10 - 40 per cent in volume within in Swedish forests compared to the volume of live trees in Swedish forests. But the industrial scale of forest exploitations, with no chance for successive dead wood establishment, only 5.7 per cent of dead wood remains (Jonsson et al. 2016 and references therein). Coarse woody debris such as snags, trunks, logs, branches, and tree stumps make up for most of the amount of dead wood in natural forest environments. When taking away these substrates from the forest environment an important part of the forest ecosystem is taken away. This results in the fact that many species, which were once common in natural forest environments, have become red listed or even have gone extinct because of the loss of these diverse natural environments that are crucial for their survival. Dead wood is a fundamental part in these forest ecosystems that interacts with a wide variety of species, thus providing for a large proportion of the biodiversity (Seibold et al. 2015:39).

Historically, natural disturbances contributed to sudden large amounts of dead wood, this was also a general phenomenon before we started to exploit forest environments on a massive scale. Natural disturbances, such as storms or forest fires, created sun exposed areas filled with dead wood in the form of snags and stumps that attracted many species of invertebrates and subsequently birds that have adapted to these naturally influenced environments. These disruptions were an essential part of the dynamic forest cycle before man started to regulate them (Hansson & Jonsell 2018:1054). Now we take away most trees before they can reach their potential age and become snags and stumps in a natural way (Fig. 1). Slash however is smaller, mostly smaller branches and twigs that are left after logging, alternatively called “logging residue”.

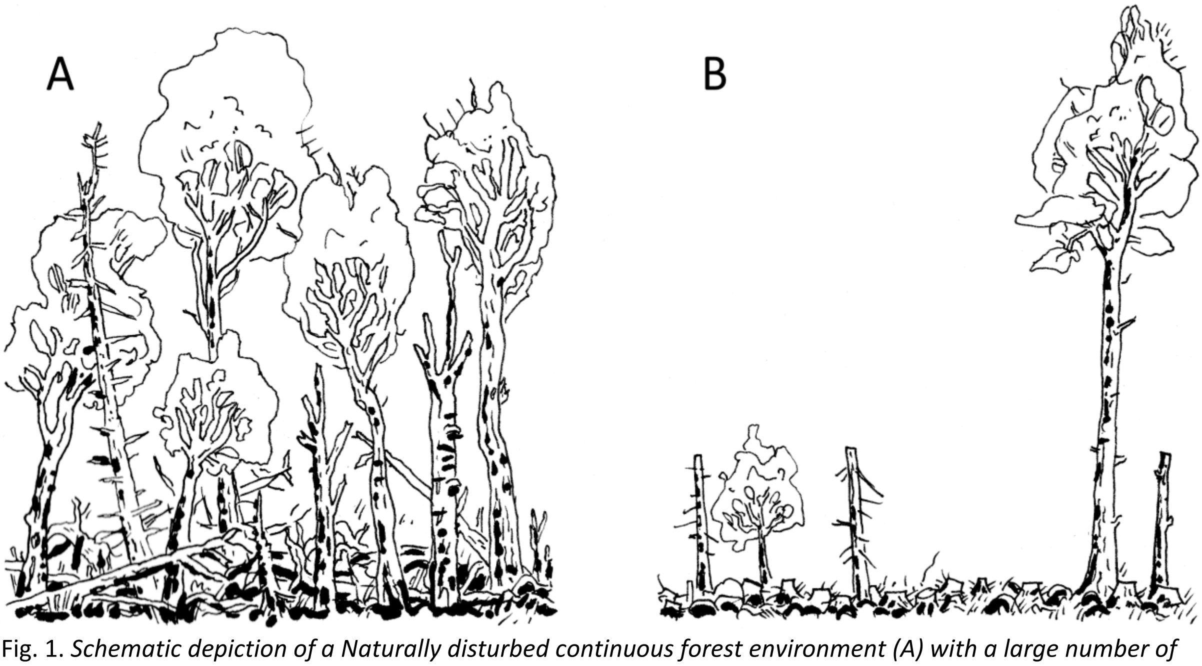

Fig. 1. *Schematic depiction of a Naturally disturbed continuous forest environment (A) with a large number of standing snags, fallen logs versus an exploited clear-cut forest environment (B) with a few high stumps, a few future trees and almost no dead wood.*

Snags and stumps (dead wood) are a very important substrate for many wood dependent beetles (saproxylic insects), fungi (saprophytic fungi) and lichens. These species have adapted in such a way that they also need each other to survive, a symbiosis. Saproxylic beetles such as the minute brown scavenger beetle *(Latridiidae sp.)* that lives of fungi in tree stumps, the rove beetle *(Staphylinidae sp.)* is a predatory insect that lives of other insects that inhabit tree stumps, the black spruce borer beetle *(Asemum striatum)* of which the larvae depend on tree stumps as a habitat for their transition before they become full grown beetles. However, since dead wood substrate amounts have decreased, a range of saproxylic beetle populations such as the Rosalia longicorn *(Rosalia alpina),* the wrinkled bark beetle *(Rhysodes sulcatus),* the bark- gnawing beetle *(Peltis grossa)* have become red-listed species. Saprotrophic fungi and lichens, which have a symbiotic relationship, have also declined significantly, the fungus *Hericium coralloides* and the lichens *Cladonia botrytes*, *Lecidea turgidula* and *Micarea* depend on dead wood substrate (Caruso 2008:27; Thorn et al. 2020:507). Lichens for example need sun-exposed dead wood substrate, but when these substrates decrease so does lichen quantity (Persson & Egnell 2018:14). As mentioned before, dead wood in all its forms is a tremendous important part in the forest ecosystem, thus, with dead wood amounts dwindling so does biodiversity. In order to flourish, these vital substrates are especially essential for dead or decaying wood dependent insects, such as saproxylic beetles, lichens and dead or decaying wood dependent fungi (saprotrophytic fungi) (Ottosson 2013:29).

Another fundamental aspect why dead wood is very important is the fact that large amounts of carbon (C) are stored in dead wood and in the forest soil. Though live trees contain the highest amount of carbon, they capture the carbon dioxide (CO_2) from the atmosphere. Through photosynthesis, solar radiation binds carbon dioxide from the atmosphere with water, which is pumped up by the tree through capillary action. This creates oxygen (O_2), and glucose ($C_6H_{12}O_6$) which is the building material for the cellulose material of the tree itself. Much of that glucose, which contains carbon is stored in their biomass, this includes the roots as well (Carbon Tree 2017). When trees die, they deteriorate and surrender to gravity. Their biomass becomes dead wood that still contains the carbon that has been accumulated during their life span. Subsequently, the dead wood breaks down in smaller pieces (forest litter). The soil in which a tree has been standing is saturated with the carbon from the finer dead wood particles, a natural dynamic ecosystem process also known as sequestration.

On a global scale, 30 per cent of carbon in organic form is manifested within the soil ecosystem (Boisvenue & Deluca 2012:176). Eventually when the stored carbon in organic form starts decomposing, it is released into the atmosphere through respiration and oxidation processes, which in undisturbed situations takes a long time. Natural disturbances like drought or sporadic forest fires accelerates these processes but since man exploits the natural forest environments by for example forestry residue and stump extraction, they disturb the soil as well. This subsequently releases even more stored carbon into the atmosphere in the form of carbon dioxide (Carbon Tree 2017). Due to most of the forest residue being transported away for processing into bioenergy, the sequestration has also become much less which contributes even more to the global greenhouse effect. This in turn sets in motion more destructive phenomena that contribute to unhealthy forest environments for example unbalanced invasions of insects, diseases, and increasing periods of drought (UNECE 2020).

1.1.2. Slash and stump handling in modern forestry and the implications on biodiversity

When clear cutting large areas of forest, not only timber and the leftover logging residue are being removed, also large portions of dead wood which has been laying or standing there before the area got to be exploited are being transported away as well. New innovations have led to new energy solutions where biomass replaces fossil fuels and subsequently making wood an attractive commodity because when it is processed into energy it has a lower carbon footprint than fossil fuels such as coal. As soon as all the logs have been transported away from a forest, the remainder slash is gathered and put in stacks which after a certain time is processed into chips on location and transported to a power station for incineration. Not only is slash being used for renewable energy, tree stumps are also a source for bioenergy thus making them a valuable energy resource to extract from forest clear-cuts as well. However, the extraction of stumps, which is called “stump-harvesting”, depends on the economy. With a bad economic situation, the extraction of tree stumps costs more then what they yield in energy (Persson & Palmér 2017:17). According to Tryggve Persson, a retired professor in soil biology, biomass prices are more interesting than environmental criteria (Persson 2017:19).

Extracting all the wood from the forest is an extensive undertaking, first a harvester drives through the area cutting the trees, then a forwarder drives through the area to pick up all the logs, after that another forwarder comes to collect all the slash drives through the area and puts all the slash into piles on the area or beside a logging road that is situated close by. After that, a heavy specialized stump-extracting machine such as a specialized excavator drives through that area breaking up all the stumps. After that, a forwarder drives through the area picking up all the stumps and places them in piles along a local logging road for further processing on location or for deportation. All this heavy industrial machine activity affects the forest ecosystem in such a way where dead wood is being grinded down and the soil is being disturbed (Hyvönen et al. 2016:7; Ranius et al. 2018:411). These exorbitant extraction methods of slash and stumps results in the decrease of important dead wood substrate in all its shapes and sizes. This causes a disturbed ecosystem and a substantial loss of biodiversity, for example the fragmentation of species populations and the destruction of fragile mycelium networks in the soil and dead wood (Jonsell & Hansson 2011:1062; Mäkipää 2015:1971; Ranius et al. 2018:421).

After extraction has been performed another problem arises where the extracted forestry residue, slash and stumps are being stacked up in piles making them an ideal habitat for all kinds of invertebrates, small mammals, and birds. They function just as deliberately made fauna depots, but these are short term depots for these species. Thus, these piles become ecological traps where species, including red-listed species, find shelter and lay their eggs. It is just a matter of time before a lorry comes along and picks up these piles to be chipped on location or get deported to an energy plant for incineration. According to Tryggve Persson and Gustav Egnell's research “Stump harvesting for bioenergy: A review of climatic and environmental impacts in northern Europe and America”, three kinds of beetle species were seven times more abundant in piles of Norway spruce *(Picea abies)* roots and stumps than in the stumps of Norway spruce on clear-cuts. If extraction of stumps would be more balanced, they suspect that regional extinction of these species would presumably be less probable (Persson & Egnell 2018:17). As a result, these clear-cuts attract many species of invertebrates that thrive in slash and stumps, become clustered in these sun exposed areas. They find their habitats in the slash and stumps which eventually will be extracted from these areas, thus becoming ecological traps as well. They are being round up on sun exposed clear-cut areas instead of living dispersed in naturally disturbed environments where slash and stump residue will remain to decompose naturally. Instead of naturally disturbed areas that occur occasionally, the over-abundance of man-made sun exposed clear-cut areas has a significant influence on the natural balance (Ranius 2017:418).

1.1.3. Creation of dead wood

For slash and stumps to decay, a range of essential organic material decomposing factors are necessary. The decomposition happens in several stages wherein organic material degrades into smaller bits and pieces by weathering down to the molecular level through the influence of microorganisms such as bacteria and fungi. The bacteria that play an important role in the degrading process of organic matter are called *Actinomycetes.* These bacteria have semi-fungal properties where they form a mycelium network in dead organic material, making them a very important link to degrade dead organic material into minerals. With larger woody debris such as big branches and tree stumps, the degradation of larger organic material into finer bits and pieces also occurs but on a macro scale, thus turning these larger substrate types into minerals over a longer period of time. Climate also influences these degradation processes where a colder temperature slows down the bacterial activity in decomposition processes (Håkansson 2000:333).

To achieve a higher amount of dead wood in a forest environment, more sustainable procedures can be implemented. These procedures are more beneficial for biodiversity and the ecosystem where dead wood in a variety of shapes and sizes is left, which is obviously far more natural than a monotonous clear-cut site. This can be achieved by excluding logging totally or by applying a more ecosystem friendly form of logging through sustainable forest management (SFM). The Lübeck forestry model for instance, is a more sustainable and ecosystem friendly way of forestry management. In this model, environmental awareness and selective felling to allow the forest to follow its own natural cycle are fundamental aspects that define the Lübeck forestry model (Dauncy 2019).

Providing different sizes of dead wood, creating sun exposed sites, leaving a diverse tree inventory are key examples for the creation of more natural forest environments. There is a range of solutions available that provide dead wood substrate in forest environments by mimicking natural disturbances in forest environments. Prescribed controlled burning can be such a solution to attract woodboring beetles that lay their eggs in burnt tree trunks and tree stumps. In these burnt tree trunks and stumps, their larvae feed on the phloem of these burnt trunks and stumps. This subsequently attracts forest birds such as woodpeckers (Walker 2019).

A common method to create dead wood is the creation of high stumps. These high stumps can often be seen on clear-cuts where a tree trunk of about 3 to 4 meters is left standing. High stumps function as a hub for invertebrates to procreate and consequently being an attractive food source for birds and other insects such as woodpeckers and predatory beetles (Andersson et al. 2015:9). Although high stumps are beneficial for biodiversity, in Persson & Egnell's review *“Stump harvesting for bioenergy: A review of climatic and environmental impacts in northern Europe and America”* they mention that low stumps did not differ in their saproxylic beetle abundance making these low stumps just as important as high stumps if you compare the number of low stumps and the number of high stumps being left after logging (2018:15). To compensate for the extracted amount of dead wood from a forest, a large number of high stumps need to be left after forestry exploits, but this is problematic when fast profit outweighs the fragile ecosystem (Ranius et al. 2018:421). High stumps are usually created in a forest where a heavy forestry machine is actively thinning trees, but high stumps can also be created manually although this is more labor-intensive (Fig. 2). Cutting a tree in half and in the process damaging the tree, creates a sun exposed snag that attracts many insects and subsequently birds for example woodpeckers and owls.

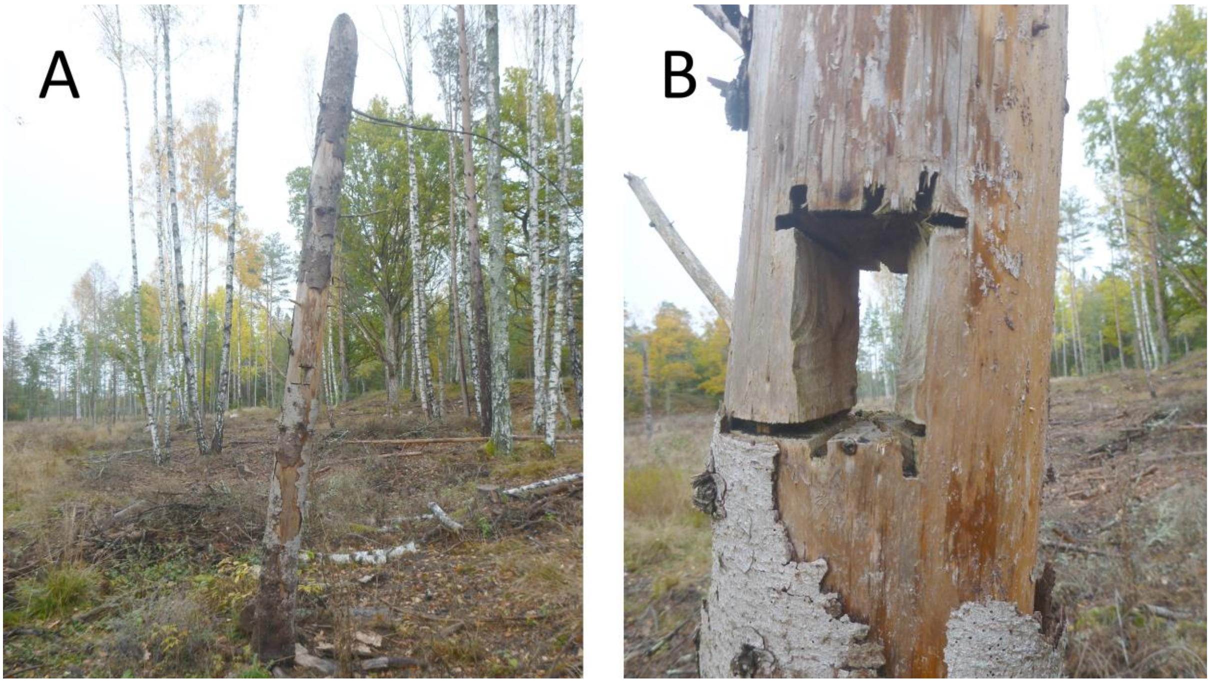

Fig. 2. *Example of a basic high stump created by a harvester cutting head (A). Afterwards holes can be cut in the high stump with a chainsaw (B).*

Then there is the veteranization method. This a method where a vital tree is damaged in order for the tree to create dead wood substrate faster. This method mimics natural disturbances such as lightning damage or wounds that are created by storms that breaks off branches. Such a method accelerates the degradation of trees. This degradation method can also be achieved by girdling a tree. Here, partial areas of bark on a tree are removed, creating a wound that stimulates decay, thus creating a future snag. Leaving the slash such as treetops, bark, and branches after implementing these methods becomes an important dead wood substrate that attracts a large variety of dead wood dependent organisms (Thorn et al. 2018:509). Leaving wind felled trees is also a solution to create dead wood substrate that increases biodiversity. Here the whole tree, has been blown out of balance, where the windthrown tree ends up hanging into other trees or has been blown down on the forest floor flipping up a part of the root system and likely damaging other surrounding trees in the process as well. This method is also beneficial for restoring exploited forests to a more natural dynamic state (Thorn et al. 2018:509).

Another method I got introduced to is a method implemented by dr Jonas Webjörn in his forestry management measures. With his method he tries to speed up degradation of tree stumps and create dead wood substrate quicker. At his estate of Rommarö, which is situated 10 km south-southeast (SSE) of Västerljung, Södermanland, he experiments with leftover standing tree stumps. He manually manipulates these tree stumps with a chainsaw after felling in such a way to try to accelerate decomposition so that these stumps get absorbed quicker by the forest ecosystem. Although he is a doctor in optical physics, he does not have an extensive education in forestry and biology. Because of his passionate interest in forestry and biology as a hobby, dr Webjörn taught himself by following short forestry courses to manage his forests with a focus on biodiversity and ecological values. In combination with his scientific background and environmental awareness he performs his green hobby through non-standard practices.

In a conversation with dr Webjörn, he explained how he came up with the idea to implement his tree stump manipulation method in his forest management activities. The main reason why he started his experimentation with manipulating tree stumps is that he got displeased by the sterile monotonous appearance of the mechanically generated tree stumps that were left after a harvester had cut down portions of his forest. Dr Webjörn, tries to restore these parts of his forest back to a more natural disturbed looking forest environment that should have the natural appearance where the natural dynamic disturbances, cycles of growth and decay are represented instead of the extensive forestry exploitation appearances with just monotonous flat stumps. This method has the benefit of leaving out heavy stump extracting machinery or scarifying machinery and makes use of the tree stumps that are already in place to create dead wood substrate. In this method tree stumps that are left after felling, are manually cut in random shapes with a chainsaw into the top surface of the remaining stump to make them look more uneven. To make a convex bowl or cutting slits vertically into the stump surface water can seep in and microorganisms can enter the stump and start degrading the wood as soon as the tree has been cut (Fig. 3). Nearby soil substrate that contains microorganisms can be taken and put into the bowl or slits in the tree stump.

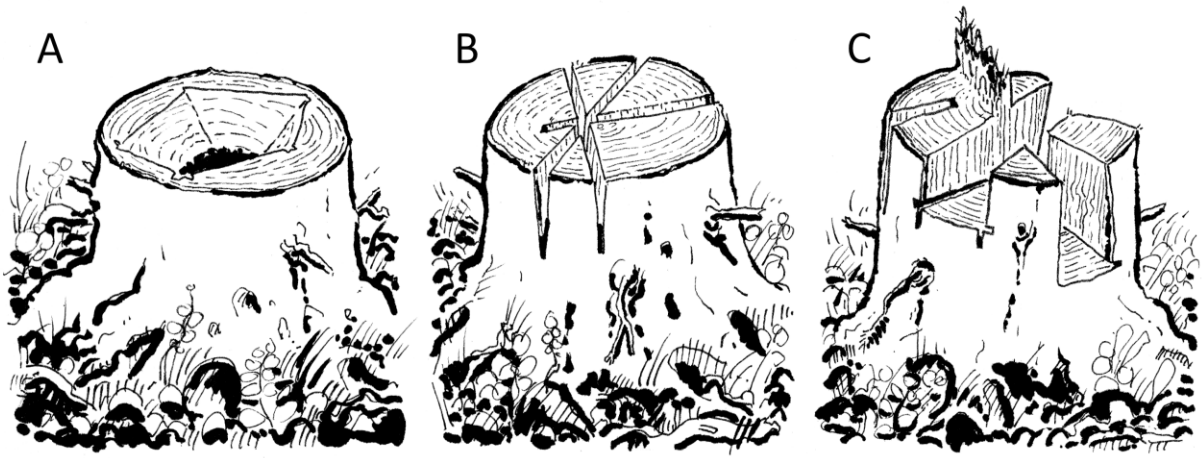

Fig. 3. *Schematic depiction of examples of manual manipulated tree stumps: A convex bowl shape (A), randomly cut slits (B), randomly cut out shapes to mimic a more natural disturbance (C).*

1.2. Problem and hypothesis

Standard forestry models include the use of heavy machinery that extract large amounts of wood from forest stands. When a last thinning or clear-cut has been done most of the slash is removed, on top of that stumps are extracted and the soil get scarified. These processes put tremendous pressure on forest environments and cause substantial decrease in biodiversity because of the shortfall of dead wood. In this study, a more sustainable method of dead wood creation is in focus. Restoring exploited forest environments by sustainable methods that mimic natural disturbances should minimize the stress to the natural balance of the ecosystem and a possibility for forest continuation to recover more swiftly. Instead of removing tree stumps from forest environments, the present tree stumps can be used to compensate for the shortfall of dead wood substrate on which a large variety of species depend.

The main questions regarding the compensation for the shortfall of dead wood hypothesis are:

- Does the tree stump manipulation method that dr Webjörn implements in his forestry management actually speed up the degradation processes in tree stumps?
- Are there any additional uses for the tree stump manipulation method to compensate for dead wood shortfall?

1.3. Goal

The goal of this thesis is to determine through statistical analysis if the superficial method where tree stumps are manipulated so that their decomposition is accelerated and works. This to compensate for the shortfall of dead wood substrate in boreal forest environments.

1.4. Limitations

This research is focused on the effects of the basic manual manipulation method of tree stumps in forest environments in general to create dead wood. The elaborate forestry methods that involve the extractions of slash and stumps are negative factors that affect the abundance of dead wood substrate. Those forestry methods are not being studied in further detail in this thesis.

More elaborate clarifications on soil compositions, how carbon sequestration functions and how the exploitation for renewable energy affects carbon storage in forest environments is kept to a minimum. Dead wood is an essential part in the forest ecosystem, it functions as a source of nutrients and as habitats for a wide range of organisms. The large variety of organisms that make use of tree stumps such as invertebrates, fungi, mosses, and lichens are very important to mention but considering large variety of species in the forest ecosystem, this is also kept at a basic level.

The experimental approach within the manipulating of tree stumps method is a process of trial and error. This research project is based on information from a basic statistical analysis. This is a deliberate choice to keep this research coherent and practically feasible.

2. METHOD

2.1. Research location

The location for this research project is situated at the privately owned forest property of dr Jonas Webjörn on the peninsula of Römora which located 7 km northeast of Studsvik and 6 km southwest of Trosa, along the east coast of Sweden (Fig.4). Römora is also known as Rommarö which is part of the Västerljung municipality, Södermanland. Rommarö covers a mix of pastures, coniferous and deciduous forests in a coastal setting surrounded by a variety of skerries. Of the 120 hectares of land at Rommarö, 98 hectares is forest landscape of which 28 hectares is nature conservation, and 70 hectares is production forest. On his property dr Webjörn manages the forests independently since 2011. Here dr Webjörn directed me to three areas where he manipulated tree stumps with a chainsaw in the past. The first inventory stand area which is situated in the southwest of Rommarö is mixed aged forest and classified as 28/S1 (Appx.), the second inventory stand area which is situated in the south of Rommarö is recent clear-cut area with free regrowth of supportive planting of pine and is classified as 32/K1 (Appx.) and the third inventory stand area which is situated south east middle of Rommarö is mixed aged forest and is classified as 34/S1.

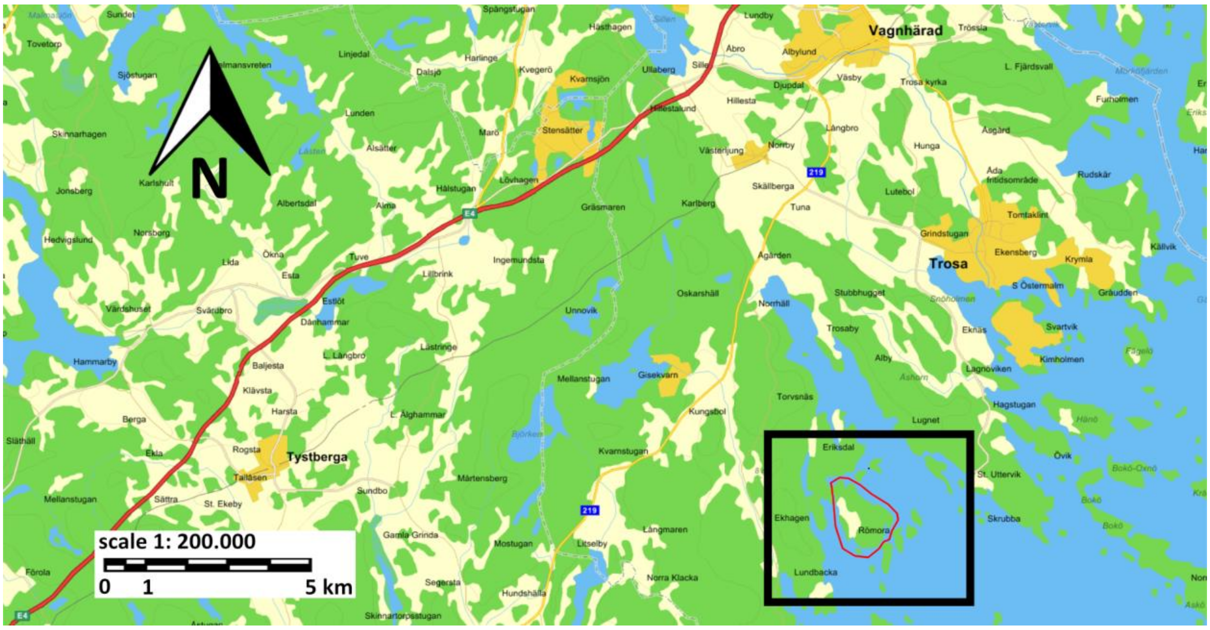

Fig. 4. *Location of Römora where the field research areas are situated. Eniro, Lantmäteriet/OptiWay AB 2021.*

2.2. Field inventory

The inventory of the tree stumps has been performed between 2020/10/21 – 2020/12/20. A total of 92 coniferous and deciduous tree stumps have been documented and probed. These tree stumps have been created with a harvester cutting head or have been created manually with a chainsaw between 2011 and 2014. A superficial metal probe, 60 cm long and 0.5 mm thick, has been used to probe every tree stump (Fig. 5). The depth of how far the probe penetrated the tree stump was measured with a measuring tape.


Fig. 5. *This image shows the metal probe and measuring tape that has been used to document all the tree stumps.*

The choice of tree stumps in the research areas was random. Out of the 92 tree stumps I could only locate and document 7 manually created tree stumps that have been manipulated with different methods to achieve the same purpose. These stumps are manipulated by using a chainsaw and can contain soil substrate and originate from 2011 up to and including 2014. The number of mechanically created tree stumps by a harvester cutting head that I have documented in these areas is 22. Whereas the remainder 70 stumps that I documented in these areas are manually created by using a chainsaw. All the stumps have been photographed if further exterior examination is necessary.

2.3. Statistical inventory

For the quantitative part in this research, T-Tests were run using IBM© SPSS© Statistics version 25 to compare medium depth levels of degradation in the different stumps. A functional table with different parameters was designed to make the results and analysis possible and visual. The data gathering procedure with the metal rod has been primitive but effective. During the processing stage I focused on the most relevant information needed to get my assumptions answered. From there graphs were made in the form of boxplots with whiskers. These prove very effective and clear to analyze distributions of the different stump observations in one graph.

Every documented tree stump has been designated with a sample number ranging from 1 to and including 92. The dimensions of the stumps have also been measured to be able to backtrack the stumps for possible future documentation. The most relevant parameters that have been gathered were: tree species, the dimensions of the documented tree stump the year of tree stump creation if it is a manually or mechanically created tree stump and if it is manipulated, depth of the tree stump decay, traces of insects that are visible on the tree stump, occurrence of fungi on the tree stump, occurrence of moss on the tree stump, occurrence of lichen on the tree stump, and the how much the bark is loosening from the wood of the stump. After having indexed all the tree stumps, the year of tree stump creation has been narrowed down to the period from 2011 up to and including 2014. This was a deliberate choice because the further back in time the more difficult it had become to read the tree stumps and their decay state, thus making it more difficult to compare. The more recent created stumps the better information there is to analyze.

2.3.1. Tree species

A fundamental statistical parameter is the tree species, this to see if the acceleration rate of decay of manipulated tree stumps is different per tree species. This is also an important parameter that shows which species of trees, coniferous or deciduous, attracts different kinds of organisms such as moss, lichens, fungi, and insects. The following stumps of coniferous and deciduous tree species that have been documented and probed in the research areas mentioned in 2.1 are: Norway maple *(Acer platanoides)*, European white birch *(Betula pendula)*, Norway spruce *(Picea abies)*, Scots pine *(Pinus sylvestris)*, European aspen *(Populus tremula)* and European oak *(Quercus robur).*

2.3.2. Mechanically created tree stump or manually created tree stump

Another essential parameter that has been indexed is the difference between mechanically created tree stumps or manual created tree stumps. Because a harvester cutting head leaves a flat surfaced stump after the tree is felled, whereas felling a tree manually with a chainsaw leaves a stump with an uneven cutting surface and a remaining felling hinge (Fig. 6). This makes the manually created tree stumps have wood fibers sticking out where moisture can penetrate more easily into the stump itself and remain moist for a longer period of time. Whereas the mechanically created tree stumps have a flat surface where moisture can run off more easily or evaporate quicker. This parameter is divided in the following categories: N: None (mechanically created with a harvester cutting head), H: Hinge cut (manually created with a chainsaw where a felling hinge remains), C: Cross incision (manually created and manipulated with a chainsaw), RC: Recess Convex (manually created and manipulated with a chainsaw), S: Straight incision (manually created and manipulated with a chainsaw).

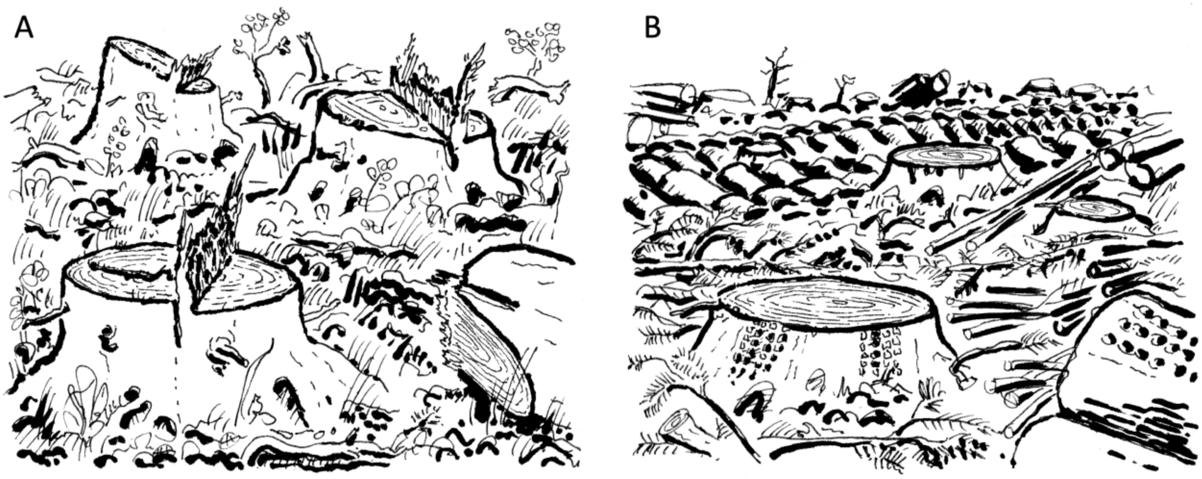

Fig. 6. *Schematic depiction of tree stumps that have been manually created by using a chainsaw, and have remaining felling hinges and have uneven surfaces after manual felling (A), and tree stumps that have been mechanically created by a harvester cutting head are usually lower and have flat surfaces after machine felling (B).*

2.3.3. Decay depth

The important parameter *decay depth,* has been categorized and measured with the metal probe on five fixed locations on every tree stumps (Fig. 7), namely; A: the decay depth of the core zone (pith and heartwood), B: the decay depth of the inner bark zone (cambium and phloem), C: the decay depth of the middle zone (sapwood), D: the decay depth of the lower side of the stump (root collar) and E: the decay depth of the upper side of the stump. Parameters D and E and are measured without the bark.

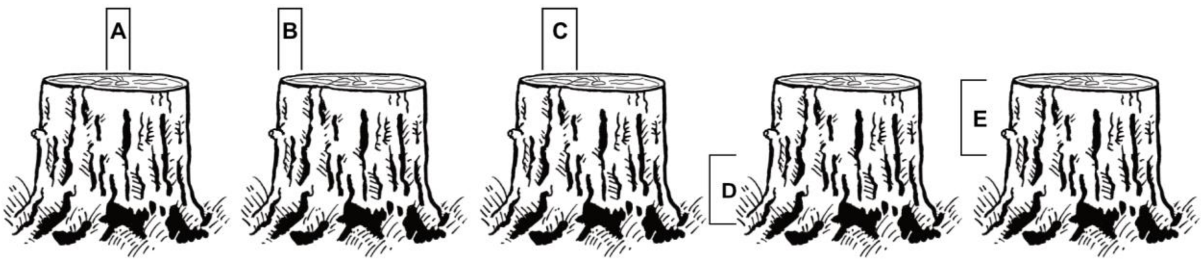

Fig. 7. *Schematic depiction of the probing location areas there a metal rod has been used to measure how deep the decomposition has progressed. A: core zone, B: inner bark zone, C: middle zone, D: lower stump side, E: upper stump side.*

2.3.4. Presence of moss, lichens, fungi

The *presence of moss, lichens, and fungi* on the tree stumps has also been categorized and might prove an essential parameter for further research. All three categories have been documented, estimated, and divided in 6 levels as followed; 0: 0 %, 1: 1 % to 19 %, 2: 20 % to 39%, 3: 40 % to 59 %, 4: 60 % to 79 %, 5: 80 % to 100 % (where 0% is no vegetation or fungi at all).

2.3.5. Presence of insect traces

Presence of insect traces can also be an essential parameter to see if the manually created tree stumps has an increasing positive effect for invertebrate abundance. Therefor the parameter that categorizes the traces of insects has been designated 0: No traces, 1: Some traces and 2: Many traces. These traces are based on their appearance in the tree stumps. This means the presence of holes as being these traces (Fig. 8).

Fig. 8. *Examples of insect traces in European aspen (A) and European white birch (B).*

2.4. Source material and criticism

Some aspects of the field inventory could have been done in a different way. Because of the limited research time to investigate the effects of tree stump manipulation, a limited amount of tree stumps has been documented on location. This limitation of the amount of tree stumps makes it more difficult to draw hard statistic conclusions. The areas that have been visited to document the different tree stumps contained an unequal number of stump types, the number of manipulated stumps that could be found was deficient compared to only manually created stumps and mechanically created stumps. The probing method by using a metal probe is not the official technique to measure wood decay. Pushing the metal probe into the stumps gives inconsistent statistical data. This is normally being done with a drill core. By using a drill core drilling perpendicularly into the tree stump, a core that is radially extracted from that drill can be weighed and studied more precise to measure decomposition rate of the stumps (Håkansson 2000:68). Unfortunately, such a drill core was not available for this research.

3. RESULTS AND ANALYSIS

3.1. Probing depths

Manually created stumps that have been generated by using a chainsaw and mechanically created stumps generated by a harvester cutting head, have been sampled and show different decay in their respective probed zones. These probing depths (A, B, C, D, and E) differ per tree species, although statistical empiric data, these are indications instead of significant statistical evidence. The decay depth in centimeters (cm) is represented on the vertical axis of the graphs. The tree species European white birch *(Betula pendula)*, Norway spruce *(Picea abies)*, Scots Pine *(Pinus sylvestris)* and European aspen *(Populus tremula)*, are most common in this inventory. Unfortunately, the documented Norway maple *(Acer platanoides)*, and European oak *(Quercus robur)* lack the numbers to get proper results compared to the other tree species.

3.1.1. Decay depth A

The decay depth A (cm) in the core (pith and heartwood) of manually created pine stumps with a basic hinge (Pine H) and manually created pine stumps with incisions (Pine C) appears to have a slightly deeper decay than mechanically created pine stumps with a flat surface (Pine N) (Fig.9). Manually created spruce stumps with a basic hinge (Spruce H) appears to have a slightly deeper decay in the core compared to mechanically spruce stumps with a flat surface (Spruce N). Aspen does not indicate any deeper decay in manually created stumps with a basic hinge (Aspen H) compared to the mechanically created aspen stumps with a flat surface (Aspen N). Manually created birch stumps with a basic hinge appear to have a slightly deeper decay in the core compared to mechanically created birch stumps with a flat surface (Birch N). The observed differences in decay depth A were non-significant.

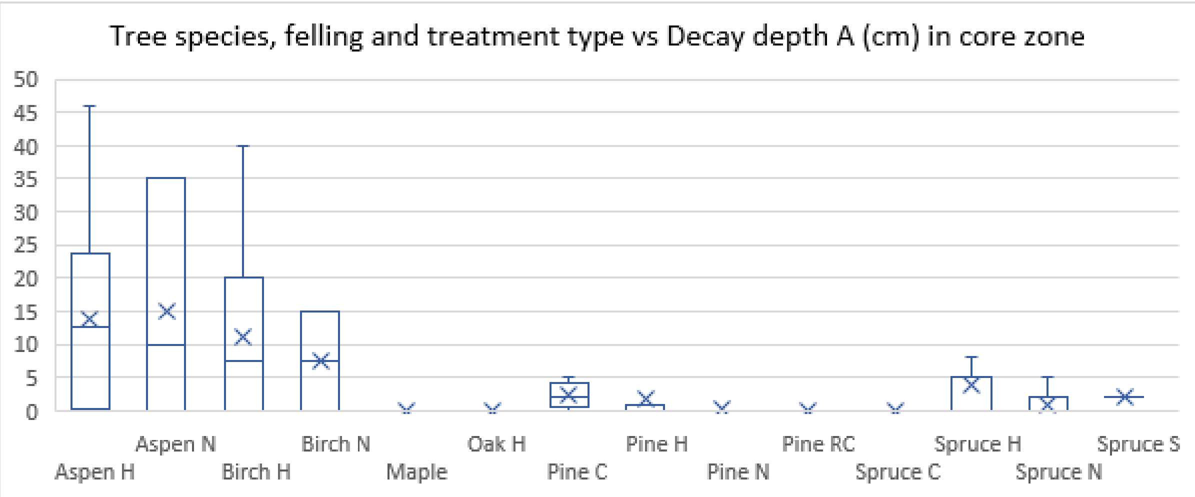

Fig. 9. *Decay depth (cm) at point A in the core zone (pith and heartwood) of manually created stumps with a basic hinge (H), manually created stumps with incisions (C, RC, and S) and mechanically created stumps with a flat surface (N). Crosses show mean values, the whiskers show spread of measurements.*

3.1.2. Decay depth B

The decay depth B (cm) in the inner bark zone (cambium and phloem) of manually created pine stumps with a basic hinge (Pine H) and manually created pine stumps with incisions

(Pine C) is considerably deeper compared to mechanically created pine stumps (Pine N) (Fig. 10). Whereas the depth manually and mechanically created stumps indicate no significant differences in decay depth in the inner bark zone of the stumps, they show practically the same values in depth B decay.

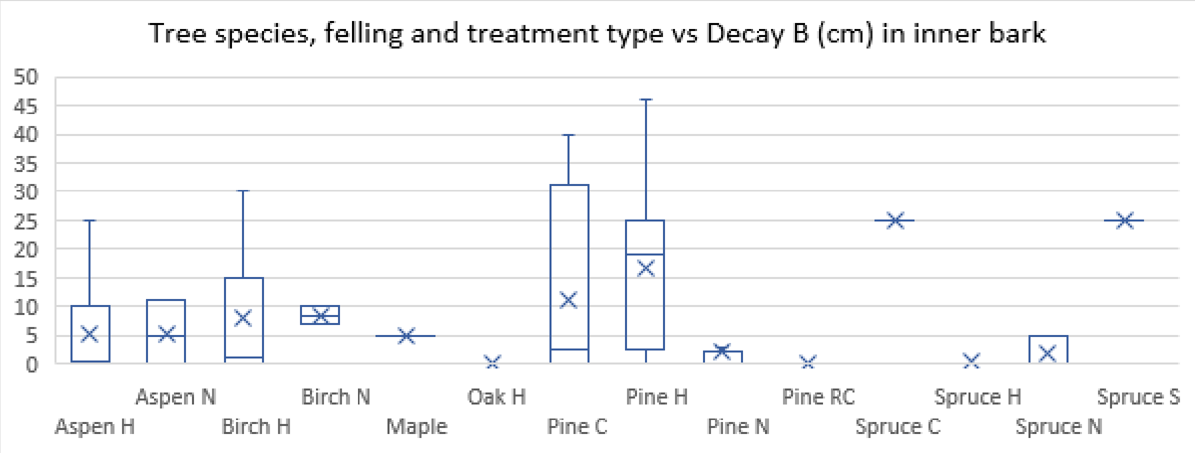

Fig. 10. *Decay depth (cm) at point B in the inner bark zone (cambium and phloem) of manually created stumps with a basic hinge (H), manually created stumps with incisions (C, RC, and S) and mechanically created stumps with a flat surface (N). Crosses show mean values, the whiskers show spread of measurements.*

3.1.3. Decay depth C

The decay depth C (cm) in the middle zone on the stumps (sapwood) of the manually created pine stumps with a hinge (Pine H) and manually created pine stumps with incisions (Pine C) appears to show some difference in decay C depth compared to mechanically created pine stumps with a flat surface (Pine N) (Fig. 11). Manually created stumps (Birch H) also appears to show a difference in decay C depth compared to mechanically created birch stumps with a flat surface (Birch N). The decay depth C (cm) in the middle zone on the stumps (sapwood) of the manually created pine stumps with a hinge (Pine H) and manually created pine stumps with incisions (Pine C) appears to show some difference in decay C depth compared to mechanically created pine stumps with a flat surface (Pine N). Manually created stumps (Birch H) also appears to show some difference in decay C depth compared to mechanically created birch stumps with a flat surface (Birch N). The observed differences in decay depth C were non-significant.

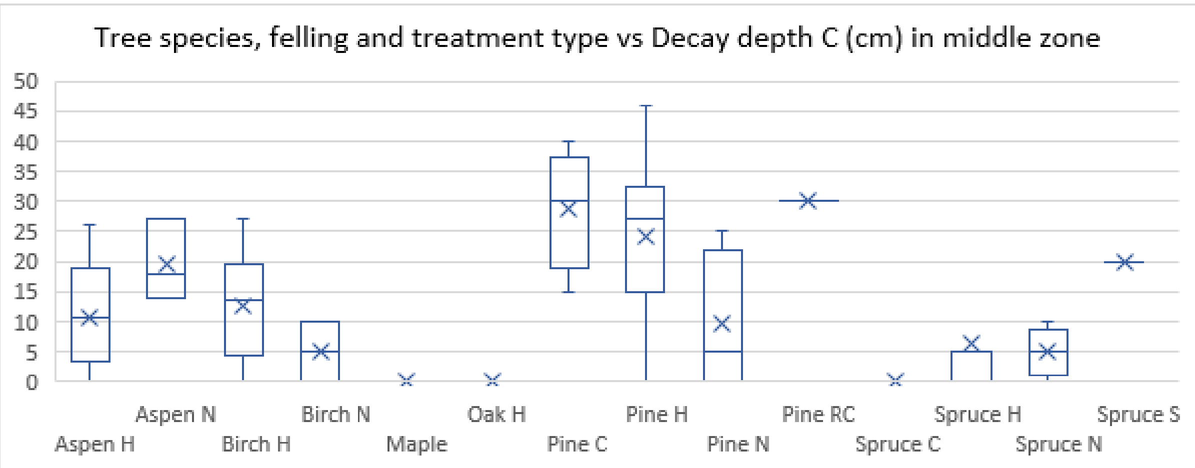

Fig. 11. *Decay depth (cm) at point C in the middle zone (sapwood) of manually created stumps with a basic hinge (H), manually created stumps with incisions (C, RC, and S) and mechanically created stumps with a flat surface (N). Crosses show mean values, the whiskers show spread of measurements.*

3.1.4. Decay depth D

The decay depth D (cm) in the lower side (root collar) of manually created spruce stumps with a hinge (Spruce H) appears to be slightly deeper compared to mechanically created spruce stumps with a flat surface (Spruce N) (Fig. 12). Whereas aspen, birch, spruce and pine indicate no significant differences in decay depth D in the lower side of the stumps, they show practically the same decay depth values. The observed differences in decay depth D were non-significant.

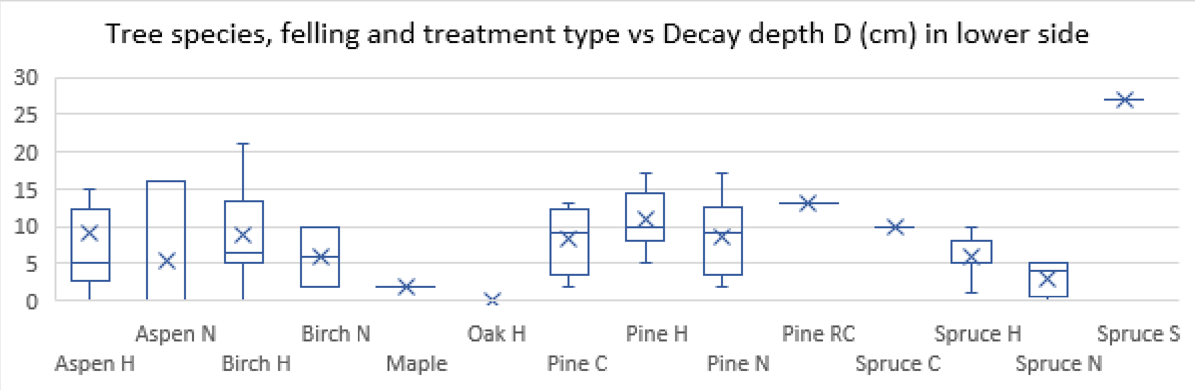

Fig. 12. *Decay depth (cm) at point D in the lower stump side of manually created stumps with a basic hinge (H), manually created stumps with incisions (C, RC, and S) and mechanically created stumps with a flat surface (N). Crosses show mean values, the whiskers show spread of measurements.*

3.1.5. Decay depth E

The decay depth E (cm) in the upper side of manually created pine stumps with a basic hinge (Pine H) and manually created pine stumps with incisions (Pine C) is considerably deeper compared to mechanically created pine stumps (Pine N) but the spread of values is large (Fig. 13), this trend appears to be of interest for the decomposition rate. Whereas aspen, birch and spruce stumps indicate no significant differences in decay depth on the upper side of the stumps, they show practically the same values in depth E decay.

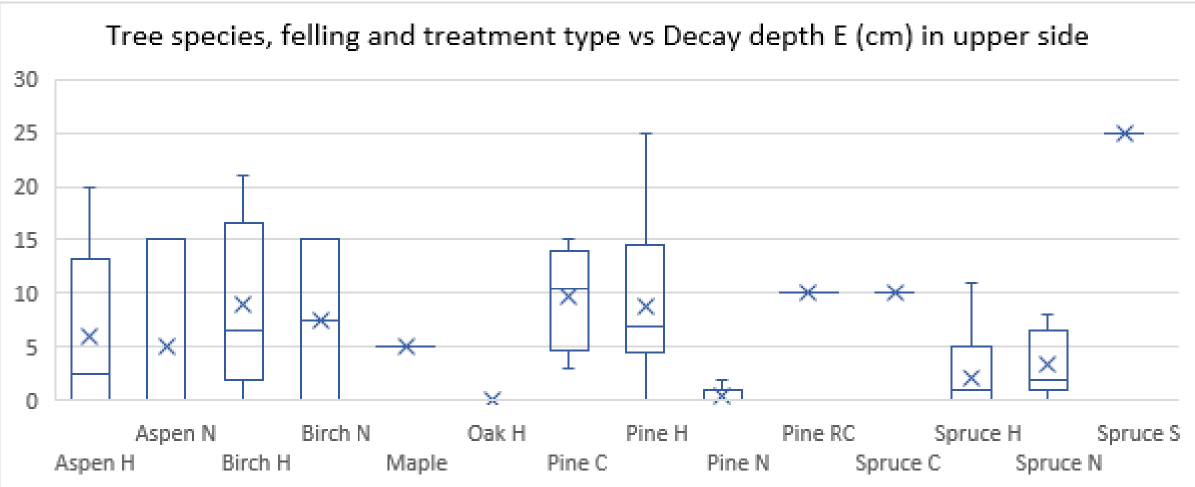

Fig. 13. *Decay depth (cm) at point E in the upper stump side of manually created stumps with a basic hinge (H), manually created stumps with incisions (C, RC, and S) and mechanically created stumps with a flat surface (N). Crosses show mean values, the whiskers show spread of measurements.*

3.2. Presence of moss, lichens, fungi, and insects

When manually and mechanically created stumps decompose into different states of decay, they become a valuable part of the ecosystem for fungi, lichens, moss, and a habitable structure for invertebrates that have been observed. The location of observation is the top surface of the stumps. The determinations of presence levels that have been observed have been translated into box plot graphs. The vertical variables for the presence level observations are: 0 = 0 %, 1 = 1 % to 19 %, 2 = 20 % to 39%, 3 = 40 % to 59 %, 4 = 60 % to 79 %, 5 = 80 % to 100 %. The observations for insect presence are categorized as: 0 = no traces, 1 = 1 traces, 2 = Many traces of insects.

3.2.1. Moss presence on stumps

Moss is most present on mechanically created spruce stumps with a flat surface (Spruce N) (Fig. 14). Manually created pine stumps with incisions (Pine C) appears to have a high presence of moss compared to pine stumps created by manual felling (Pine H) and mechanically created pine stumps (Pine N).

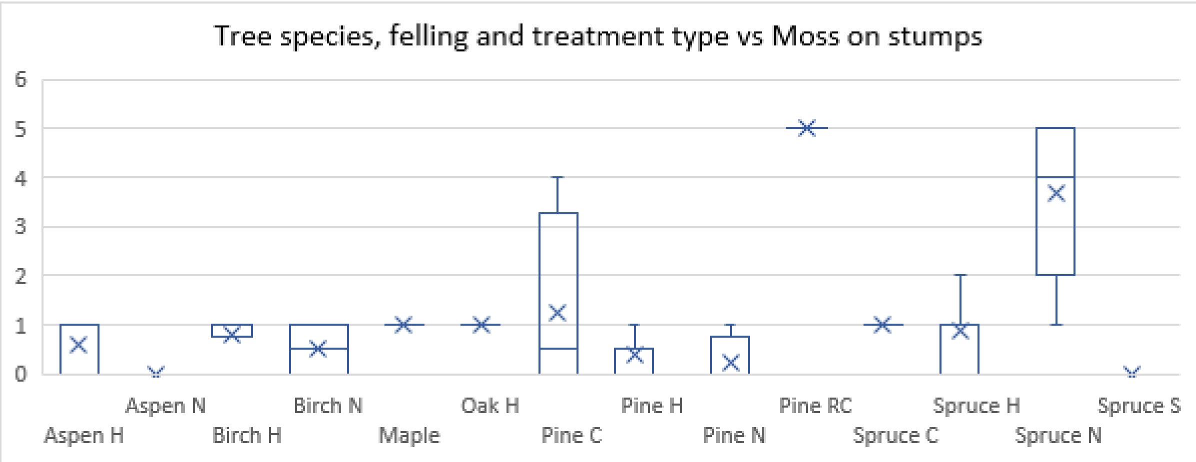

Fig. 14. *Presence level of moss on manually created stumps with a basic hinge (H), manually created stumps with incisions (C, RC, and S) and mechanically created stumps with a flat surface (N). Crosses show mean values, the whiskers show spread of observations.*

3.2.2. Lichen presence on stumps

Lichens appear to have a higher presence on manually manipulated pine stumps with an incision (Pine C) compared to manually created pine stumps (Pine H) and mechanically created pine stumps with a flat surface (Pine N) (Fig. 15). Lichens also occur on manually created birch stumps with (Birch H) and no presence of lichens on mechanically created birch stumps with a flat surface (Birch N).

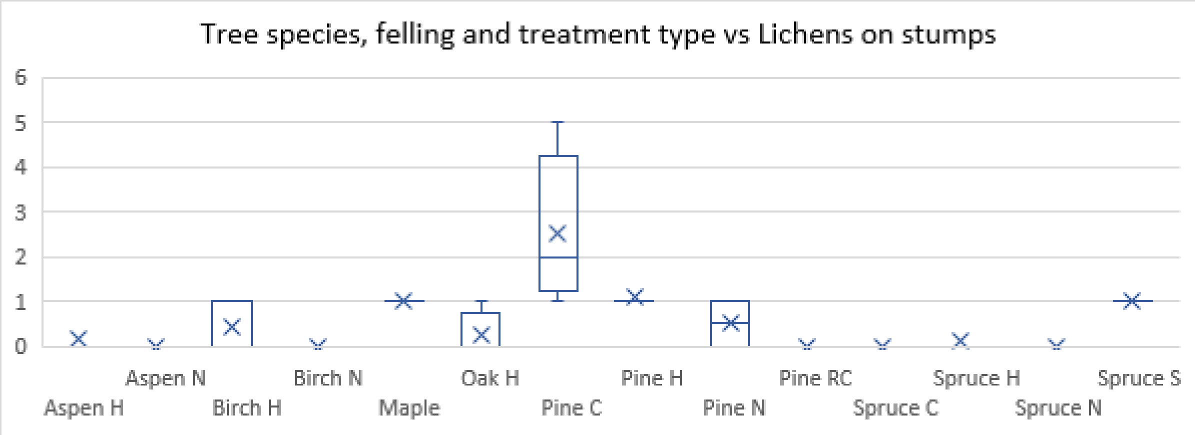

Fig. 15. *Presence level of lichens on manually created stumps with a basic hinge (H), manually created stumps with incisions (C, RC, and S) and mechanically created stumps with a flat surface (N). Crosses show mean values, the whiskers show spread of observations.*

3.2.3. Fungi presence on stumps

Manually created pine stumps (Pine H) appears to have more fungi on their exterior compared to mechanically created pine stumps with a flat surface (Pine N) (Fig. 16). Mechanically created spruce stumps with a flat surface (Spruce N) appears to have more fungi compared to manually created spruce stumps (Spruce H). Birch appears to have most fungi presence, both on manually created stumps (Birch H) and mechanically created birch stumps with a flat surface (Birch N). The mean presence level of fungi that is present in manually created stumps with a basic hinge (Birch H) appears to be higher than the mean presence level in mechanically created stumps with a flat surface (Birch N). For aspen stumps there is no difference in fungi presence on either manually created aspen stumps with a basic hinge (Aspen H) and mechanically created aspen stumps (Aspen H). The observed differences in fungi presence were non-significant.

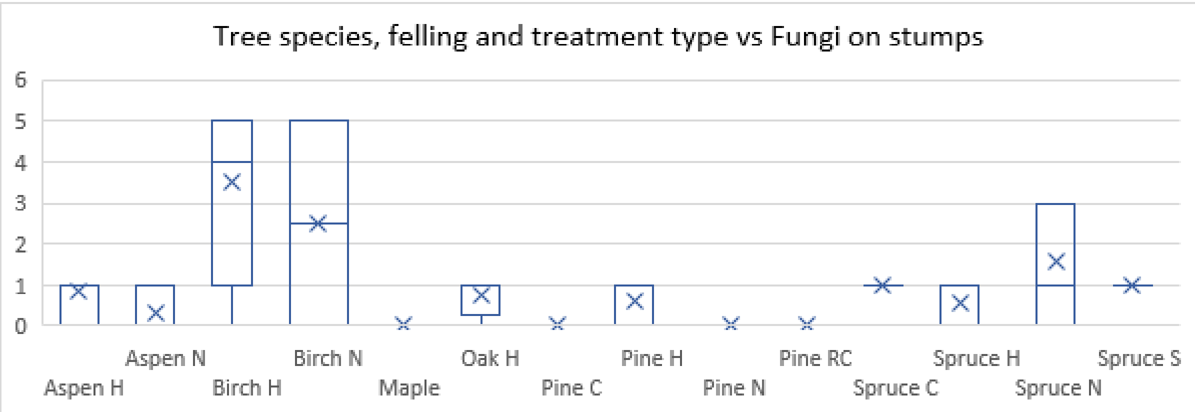

Fig. 16. *Presence level of fungi on manually created stumps with a basic hinge (H), manually created stumps with incisions (C, RC, and S) and mechanically created stumps with a flat surface (N). Crosses show mean values, the whiskers show spread of observations.*

3.2.4. Insect presence in stumps

Observed presence of insect traces in manually created stumps of aspen with a basic hinge (Aspen H) and birch stumps with a basic hinge (Birch H), appears to be twice as much abundant than in the mechanically created stumps of aspen (Aspen N) and birch (Birch N) stumps (Fig. 17). Whereas manually created stumps of pine and spruce stumps do not differ from mechanically created of pine and spruce stumps. However, manually created stumps of spruce (Spruce H) slightly appear to contain more traces of insects compared to mechanically created stumps of spruce (Spruce N). Based on the observation of insect presence, the vertical levels for this observation have been categorized as: 0 = no traces, 1 = 1 traces, 2 = Many traces of insects. Level 3 was considered but none of the stumps showed a very large presence of insects.

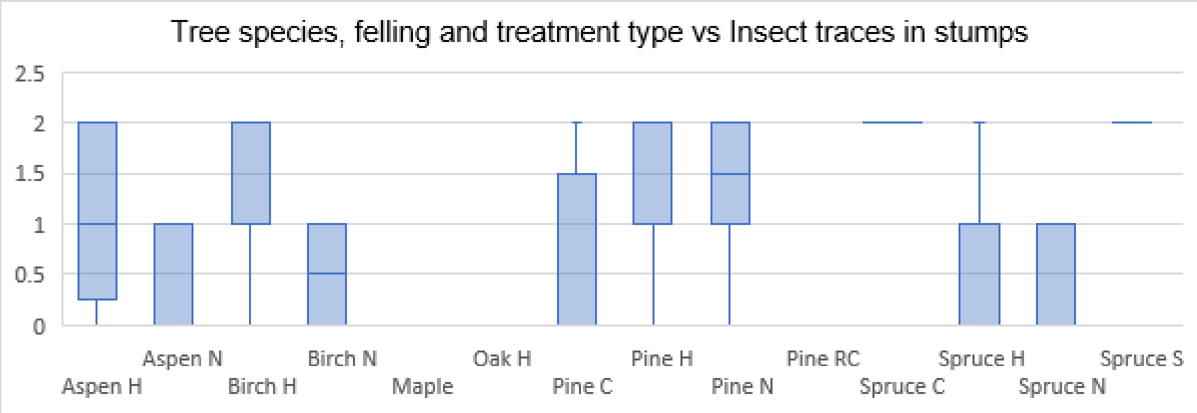

Fig. 17. *Presence level of insects on manually created stumps with a basic hinge (H), manually created stumps with incisions (C, RC, and S) and mechanically created stumps with a flat surface (N). The whiskers show spread of observations. Note: the vertical values 0, 1, and 2 are the main categories in insect traces.*

4. DISCUSSION AND CONCLUSIONS

4.1.1. Manual felling and manual manipulation effect on decomposition of dead wood

To my surprise no solid evidence could be found in the results that proves that the manual manipulation method significantly accelerates the decomposition rate in tree stumps to compensate for the shortfall in dead wood substrate. There are however small indications where manual manipulation with a chainsaw does appear to have a slight effect on decomposition rate in the middle zone (Decay depth C) of Scots pine (Pine C) (Fig. 11) and the decay in the upper side (Decay depth E) of Scots pine (Pine C) (Fig. 13). These graphs indicate that the decomposition tends to be influenced by both manual felling and manual manipulation (Pine H, C, RC). However, the question remains if it is the manual manipulation that has an effect on the manually created Scots pine stumps, or if it is that manually felling alone that is enough to accelerate decomposition. These results are too few to observe precise differences.

4.1.2. Effect of manual felling and manual manipulation on organism presence

Moss appears to have a significant presence on manipulated Scots pine stumps (pine C) compared to all the other manually created and manipulated stumps of the other tree species. That there appears to be a high presence of moss on manipulated Scots pine stumps might be caused by the fact that dr. Webjörn has added soil or moss substrate onto the stumps where it stays easier and cannot rain off or be blown away by winds. Though mechanically created Norway spruce stumps have a more abundant moss coverage then manually created Norway spruce stumps, this might be caused by the fact that they stand in a less sun-exposed location where they have been documented. Lichens also appears to have a significant presence on manipulated Scots pine stumps (Pine C), the graph also shows a higher mean value (Fig. 15). This means that the manipulation method appears to have a considerable positive influence on lichen presence that prefer these manipulated pine stumps. Fungi appear to prefer both manual and mechanically created European white birch stumps (Birch H, Birch N) and mechanically created Norway spruce stumps above the other tree species in the inventory (Fig. 16). The presence of fungi on these mechanically created stumps is also higher but makes the influence of the manual stump creation less obvious for occurring just on manually created stumps.

The most interesting result that has come forward from sampling organisms on tree stumps is that manual created stumps of European aspen and European white birch stumps appear to be beneficial for insects (Fig. 17). Although that the amount of sampled deciduous tree stumps is limited, this does indicate that insects prefer to inhabit manually created stumps compared to the mechanically created stumps of the above-mentioned tree species. Scots pine also indicates a higher presence of insects on both manually and mechanically created stumps. The decomposition results in this research did not show that the manipulation method had a direct effect in decomposition acceleration in the sampled tree stumps. However, organisms such as moss, and insects appear to thrive better on manually and manipulated stumps in general (Fig. 14, Fig. 17). This compared to the organism abundance in and on most mechanically created tree stumps. From this perspective, the manipulation of tree stumps to try to accelerate their decomposition is an interesting measure that at least can benefit biodiversity.

4.2. Manual manipulation as a forestry management measure

Although no significant results that stand out where manual manipulation accelerates decay, small trends in the results appear to have potential for further research for example the manual creation and manipulation Scots pine stumps (see 4.1.1). But that research must be done on a larger scale in better conditions and tools to get proper measurements. Accelerating tree stump decomposition provides dead wood substrate quicker in forest environments that have been emptied of most of the coarse dead wood. From that perspective no heavy forestry machinery is needed to extract and deports these stumps. In this way destructive disturbances by large machinery can be avoided (Hyvönen et al. 2016:7). On top of that, unnatural soil disturbances caused by heavy forestry machinery releases large amounts of carbon dioxide into the atmosphere that is otherwise stored in dead wood and soil (Carbon Tree 2017; Boisvenue & Deluca 2012:176). The extraction of logs, slash, and stumps as a bio-energy resource from boreal forest environments cost large amounts of energy to create energy which is contradictory. Especially when the world plans to become carbon neutral by 2050 stump extraction also must become obsolete because incinerating stumps to create energy emits a lot of carbon dioxide into the atmosphere (Carbon Tree 2017).

Biodiversity also suffers from slash and stump extraction, creating large sun exposed areas that attracts insects that thrive in sun exposed dead wood (Hansson & Jonsell 2018:1054). As mentioned earlier, coarse dead wood gets taken away and the stumps get extracted, this threatens many dead wood dependent species that interact with these stumps. It also disturbs the forest soil that not only releases carbon dioxide but also damages important mycelium networks (Jonsell & Hansson 2011:1062; Mäkipää 2015:1971; Ranius et al. 2018:421). If further research into the effects of tree stump manipulation to accelerate decomposition provides more solid evidence to prove that it actually does speed up decomposition, then that method can support the arguments why heavy machinery should be avoided. If such solid proof could be deduced from better research in the stump manipulation method that dr. Webjörn experiments with, could become an interesting alternative to compensate for the shortfall in dead wood substrate to restore forest ecosystems by turning stumps into different stages of decay. It could become an interesting method for implementation in more sustainable forestry management models as (see 1.1.3). This is also an aspect that should be researched further to be able to draw solid conclusions.

A suggestible experiment can be to use organic fertilizer to put into the manipulated stumps to provide microorganisms with more nitrogen (N) to see if that accelerates decomposition. There is, however, a catch to the acceleration of tree stump decomposition. As mentioned in 1.1.1., dead wood contains large amounts of carbon which includes the root structures as well, when speeding up decomposition processes it releases carbon faster, this is not exactly carbon neutral (Carbon Tree 2017). Therefore, it can be suggested that the tree stump manipulation method to accelerate decomposition should not be used on a large scale. However, it can be a useful method for smaller patches of logged forests.

According to the data on organism presence, which is unfortunately limited, the tree stumps that are created manually appear to have an effect on insect presence in European aspen and European white birch (see 4.1.2.). From this can be deduced that stumps of manually felled deciduous trees already are enough to mimic natural disturbances that are beneficial for biodiversity. This could be explained by the fact that natural disturbed stumps where the tree has broken off creates a large uneven surface with lots of fibers are sticking out compared to mechanically created stumps that have a flat surface. These flat surfaces might be more difficult for insects to penetrate and reach nutritious substrate (Walker 2019). Manually felling a tree creates a stump that partially has a flat surface and partially a felling hinge where fibers are sticking out, in that regard a semi-naturally disturbed stump is created (Fig. 18). These stumps with felling hinges are more beneficial for organisms to establish a foothold compared with flat surfaced stumps.

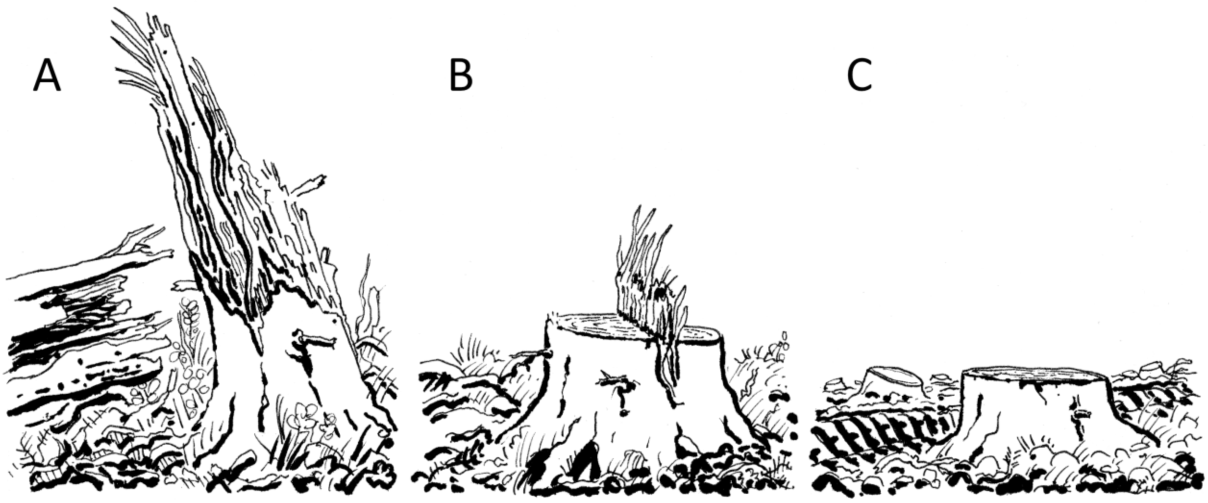

Fig. 18. *Schematic depiction of a Stump created by natural disturbances (A), a stump created by manual felling with a chainsaw (B), a stump created mechanically by a harvester cutting head (C).*

This implies that manually felled trees do not necessarily need extra tree stump manipulation measures. It depends also on the tree species and therefore knowing which stumps are affected and which are not, can be useful for future forest management. From dr Webjörns point of view, the aesthetics of naturally disturbed forest environments where the continuous cycle of life is represented in all shapes and sizes, is an important part of why he experiments with manipulating tree stumps. Forest environments where logging has occurred are deplorable wastelands that consists mostly of flat stumps, disturbed soil, and deep tracks created by heavy forest machinery. To restore these parts of logged forest into more natural looking forests, his method could be used to create dead wood that mimics natural disturbances which is beneficial for biodiversity (Thorn et al. 2018:509). In that regard, both biodiversity and aesthetics could benefit from implementing the tree stump manipulation method.

Apart from high stumps, wind fallen trees, standing snags, and damaged trees that attract a variety of insects that need these types of dead wood, low stumps in different shapes and sizes. Mechanically created low stumps with flat surfaces can be made more accessible for other species that thrive in dead wood closer to the forest floor by implementing the stump manipulation method (2018:509). Manipulating stumps to mimic natural disturbances by filling them with organic material and leaving dead wood in a variety of sizes, logged forests could be restored in a faster pace. This would also make them more naturally disturbed looking. Creating different sizes in coarse dead wood, can also be a measure to create a gradual matrix to connect a logged patch of forest to bordering forests that benefits biodiversity (Graae 2000:720).

For property owners in Sweden that have substantial natural forests situated on their property, personal preferences play an important part in how they manage their forests. Economy can be a factor for that makes these owners decide to go for production instead of natural values, corporate forest management companies influence these decisions with marketing tactics that benefit the forest industry where profit is prioritized over sustainable natural environments (Persson 2017:19; Protect the Forest, Sweden & Greenpeace Nordic 2021). For dr Webjörn however, who has the time for experimentation, economy is of lesser importance compared to the ecological values of a natural dynamic forest environment. This substantial factor makes it possible to continue with experimentation on dead wood substrate in his natural dynamic forest environments at Rommarö. It can also be an interesting initiative for a citizen science project where different forest owners who have the time to collaborate with national and international universities.

4.3. Conclusions

In this research the tree stump manipulation method has been studied to see if that method accelerates decomposition in dead wood to compensate for the shortfall in dead wood substrate. By analyzing the samples, it can be concluded that the tree stump manipulation method does not prove a significant acceleration in the decomposition of tree stumps. There are however a limited number of minor indications that have come forth from the quantitative analysis that show slightly deeper decay depths in manually manipulated stumps compared to only manually created stumps. The analysis does show and indication of more insect traces in manually created stumps that have not been manipulated with the tree stump manipulation method. Therefore, to get a better understanding, this research can be a subject for further research. However, stump manipulation could be an interesting measure to restore exploited forest environments by mimicking natural disturbances.

4.4. Reflections

It is important to bear in mind that the location (sun exposure or shadow) of the tree stumps and the in-situ moisture levels might influence the decomposition processes, these have not been recorded. The recent age of the stumps (2011-2014) spreads out over just four years and is a too short period to observe and compare wood decomposition. Also, the amount, which is 92 tree stumps, is too small to get proper results. This makes the variation of the sample stumps stand out too much. Therefore, any future research, a national or international collaboration regarding the decomposition rate and how to influence tree stumps should be done with a larger but equal number of stumps on different locations independent from each other. The different methods in stump creation should be better documented where every location has one specific method to document same-aged stumps that come from the same tree species. Climate conditions should also be considered. The sampling should be done over a longer period of time to be able to see more solid results.

5. Summary

5.1. Summary in English

Forest ecosystems are a crucial part of the global ecosystem, it is an essential motor that for instance generates oxygen, provides food and shelter for the survival of human species and for the survival of countless other species that depend on these natural dynamic forest environments. With the current exploitation of global forest environments, we put a tremendous strain on these important ecosystem services. It also releases large amounts of carbon that over a long period of time has been stored in forest soils through carbon sequestration processes. Natural dynamic forests are turning into monocultural production forest environments which are being harvested for the materials needed to meet our growing consumptive demands. Ecosystem services and biodiversity are being affected by exploitation methods where large forestry machines come in to extract the logs, slash, and stumps to be used as a resource for paper mass and bioenergy.

The extraction of stumps alone is a destructive undertaking that affects biodiversity where species that were once common have become red-listed and the forest continuation cycle is disturbed through the elaborate logging and resource extraction. These exploits cause a shortfall in dead wood substrate because the natural continuous provisioning of coarse dead wood substrate and its interaction with a large variety of species is taken away. Forests are an economic currency; biomass prices are more interesting than environmental criteria. However, other forestry management alternatives show certain more promising ecosystem friendly forestry management methods that can be implemented to avoid these kinds of monotonous clear-cut environments. For example, selective felling forestry models, where forest continuity provides dead wood which is of high importance for natural forest ecosystems to function as a symbiosis and to maintain a large biodiversity that interacts with different kinds of dead wood substrate in all shapes and sizes.

The creation of coarse dead wood substrate that benefits biodiversity in exploited forest areas and to attempt to erase the deplorable aesthetics of these damaged environments, are the main reasons why dr Jonas Webjörn started to experiment with his tree stump manipulation method in his forest at Rommarö, Trosa kommun. In this method mechanically created tree stumps with flat surfaces that are left after logging, are sawn into to create more naturally disturbed looking stumps which he then sometimes covers with forest soil substrate or other organic matter, such as mosses. This tree stump manipulation method had become the main subject for this thesis. This raised the following questions that needed to be answered:

- Does the tree stump manipulation method that dr Webjörn implements in his forestry management actually speed up the degradation processes in tree stumps?
- Are there any additional uses for the tree stump manipulation method to compensate for dead wood shortfall?

To prove if the stump manipulation method accelerates decomposition processes in tree stumps, a few research boundaries had to be introduced. Aspects such as in-depth forestry management methods, carbon and soil compositions have been kept to the basics. At dr Webjörns property areas were selected where he has manipulated tree stumps with a chainsaw in the past. 92 stumps of European white birch *(Betula pendula)*, Norway spruce *(Picea abies)*, Scots Pine *(Pinus sylvestris),* European aspen *(Populus tremula),* Norway maple *(Acer platanoides)*, and European oak *(Quercus robur)* have been selected because they are the most common stumps to be found in those areas. These stumps were either manually created through manual felling with a chainsaw or mechanically created by a harvester cutting head from 2011 up to and including 2014. The decay in these stumps has been sampled with a metal probe to measure decay depth at five fixed locations on every stump. However, this could have been done with a drill core instead in order to get more precise sample data. Observation of the exterior of the stumps to look for the presence of moss, lichens, fungi, and insects have also been documented. All the data of these parameters has been indexed with statistical software. A straightforward T-Test was selected to generate a basic overview of the data that subsequently has been used to generate a set of graphs for further analyzing.

When having analyzed the generated graphs, they showed no significant effect on stumps that were manually manipulated by using a chainsaw. However, there seemed to be some small indications in the middle zone and upper side of manually manipulated Scots pine stumps that appear to be influenced by the manual manipulation method. But it remains unclear whether or not this could have been influenced by the fact that the Scots pine stumps have been created by manual felling alone because those values are also higher compared to their mechanically created stump counterparts. The graphs for the presence of moss, lichens, fungi, and insect traces on the stumps showed that the presence of moss is high on manually manipulated Scots pine stumps. Additionally, the generated graphs showed that the traces of insects are significantly higher in manually created stumps of European aspen and European white birch than their mechanically created stump counterparts. The values for the presence of insects on Scots Pine also indicated to be a high on both manual manipulated stumps and manually created stumps. From the analyzed data no solid conclusion could be drawn. Because of the small amount of data that has been gathered, the values showed no solid proof but rather indications that the manual manipulation method and manual felling appear to have some effect. That fact that the samples showed some indications where tree stump manipulation is applied, could be an argument to advise for further research.

If further research shows that accelerating decomposition in tree stumps works by implementing the unproven experimental tree stump manipulation method, this could be a sustainable way to create dead wood in different stages of decay. From that perspective, stumps could be left standing after logging to be manipulated so they become dead wood substrate more swiftly. This also leaves out heavy stump extracting machinery which use up large amounts of energy to extract these resources to produce energy and greenhouse gasses while the world wants to become carbon neutral by 2050. To accelerate decomposition of tree stumps, it could be interesting to experiment with different kinds of organic fertilizers that are put onto manually manipulated stumps. The downside of accelerating dead wood decomposition is that dead wood contains large amounts of carbon that will be released more swiftly. This could make the tree stump manipulation method only applicable to small forest clear-cuts.

Interestingly, stumps created by manually felling did in fact contain a higher presence of insects compared to stumps created by machine felling, this could lead to the assumption that manually felled stumps closely resemble those created by natural disturbances. Because dr Webjörn tries to change the deplorable look of past clear-cut areas in his forest by creating natural disturbances, he also restores the possibilities for a more swiftly re-establishment for a variety of species that depend on dead wood by making stumps look as if they have been caused by natural disturbances. Time and economy are factors that influence where one’s priorities lie.

In conclusion, the statistics show that the tree stump manipulation method does not accelerate the decomposition processes in tree stumps. No solid evidence could be found that proves that method of dr Webjörn actually works. However, there appear to be indications that show a slight increase in insect presence in European aspen and European white birch. The indications appear to show that dr Webjörn’s tree stump manipulation method has a beneficial effect on biodiversity. To get better results, more thoroughly organized research in the study of the tree stump manipulation method is required.

5.2. Summary in Swedish

Skogsekosystem är en oersättlig del av det globala ekosystemet. Den är en avgörande motor som till exempel genererar syre, ger mat och skydd för vår överlevnad och möjliggör överlevnaden av otaliga arter som är beroende av dessa naturliga dynamiska miljöer. Med det nuvarande utnyttjandet av dessa naturliga dynamiska skogsmiljöer utsätter vi dessa naturliga dynamiska skogsekosystem för en enorm belastning. Stora mängder kol släpps ut, som under lång tid har lagrats i skogsmark genom kolbindningsprocesser. Naturliga dynamiska skogar förvandlas till monokulturella skogsmiljöer som skördas för de material som vi behöver för att möta våra växande konsumtionsbehov. Ekosystemtjänster och biologisk mångfald påverkas av exploateringsmetoder där stora skogsmaskiner används för att extrahera stockar, grot och stubbar som ska användas som en resurs för pappersmassa och bioenergi.

Utvinning av stubbar är i sig ett destruktivt företag som påverkar biologisk mångfald där arter som en gång var vanliga har blivit rödlistade. Skogens fortsättningscykel störs av de omfattande avverkningsmetoder som orsakar brist på död ved eftersom den naturliga kontinuerliga tillförseln av grovt död vedunderlag och dess interaktion med ett stort antal arter tas bort. Skogar är en ekonomisk valuta där vinst får gå före biologisk mångfald. Andra skogsbruksalternativ visar dock mer lovande ekosystemvänliga skogsbruksmetoder som kan implementeras för att undvika denna typ av monotona kalavverkade miljöer. Till exempel selektiva avverkningsskogsmodeller, där skogskontinuitet ger dött virke vilket är mycket viktigt för naturliga skogsekosystem att fungera som en symbios och för att upprätthålla en

stor biologisk mångfald som samverkar med olika typer av dött vedunderlag i alla former och storlekar.

Skapandet av grovt dött vedunderlag som gynnar biologisk mångfald i exploaterade skogsområden och en strävan att förbättra estetiken i dessa skadade miljöer är de främsta anledningarna till att dr Jonas Webjörn började experimentera med sin manipulationsmetod för trädstubbar i sin skog på Rommarö i Trosa kommun. I denna metod förändras maskinfällda trädstubbar med plana ytor som lämnats efter avverkning genom att sågas till mer naturligt störda stubbar som ibland täcks med jord eller annat organiskt material som mossa. Denna metod för manipulation av trädstubbar hade blivit huvudämnet för denna avhandling. Detta väckte följande frågor som behövdes besvaras:

- Påskyndar manipulationsmetoden för trädstubbar som dr Webjörn implementerar i sin skogsförvaltning faktiskt nedbrytningsprocesserna i trädstubbar?
- Finns det några ytterligare användningsområden för manipulation av trädstubben för att kompensera för död vedbrist?

För att utreda om stubbehandlingsmetoden påskyndar nedbrytningsprocesser i trädstubbar måste några begränsningar av studien införas. Endast grunderna har behandlats för aspekter som djupgående skogsbruksmetoder, kol- och jordkompositioner. På dr Webjörns ägor valdes områden ut där han tidigare manipulerat trädstubbar. 92 stubbar av vårtbjörk (Betula pendula), gran (Picea abies), tall (Pinus sylvestris), asp (Populus tremula), lönn (Acer platanoides) och skogsek (Quercus robur) har valts ut eftersom de är de vanligaste stubbarna i dessa områden. Dessa stubbar skapades antingen manuellt genom fällning med motorsåg eller mekaniskt med en skördare från 2011 till och med 2014. Förfallet i dessa stubbar har testats med en metallprob för att mäta förmultningsdjup på fem fasta platser på varje stubbe, men detta borde ha har gjorts med en borrkärna istället för att få mer exakta provdata. En undersökning av stubbarnas utsida avseende förekomst av mossa, lavar, svampar och insekter har också dokumenterats. All data för dessa parametrar har lagts in i statistisk programvara. Ett grundläggande T-test användes för att generera en grundläggande översikt över de data som därefter har använts för att skapa en uppsättning grafer för vidare analys.

I denna analys visade graferna inte någon signifikant inverkan på manuellt manipulerade stubbar. Det verkade emellertid finnas några små indikationer i mittzonen och övre sidan av manuellt manipulerade stubbar på att den manuella manipulationsmetoden har inverkan. Emellertid förblir det oklart om det också kunde ha påverkats av det faktum att redan tallstubbar från manuellt fällda träd har högre värden än stubbar kapade med skördare. Diagrammen för yttre närvaro av mossa, lavar, svampar och insektsspår visade att närvaron av mossa är hög på manuellt manipulerade tallstubbar. De genererade graferna visade också att spåren efter insekter är betydligt mer omfattande på manuellt skapade stubbar av asp och vårtbjörk än deras mekaniskt kapade motsvarigheter. Värdena för närvaron av insekter på tall indikerade också att de var höga på båda manuellt manipulerade stubbar och manuellt fällda stubbar. Från de analyserade uppgifterna kunde ingen entydig slutsats dras, på grund av den begränsade mängd data som har samlats in visar värdena inga solida bevis utan snarare indikationer på att manuell manipuleringsmetod och manuell avverkning verkar ha en positiv inverkan. Att proverna tyder på att manipulation av trädstubbar har positiv inverkan kan vara ett ämne för vidare forskning.

Om ytterligare forskning visar att nedbrytning av trädstubbar påskyndas genom tillämpning av den obevisade experimentella metoden för manipulering av trädstubbar, kan det vara ett hållbart sätt att skapa dött virke i olika nedbrytningsstadier. Ur det perspektivet kan stubbar lämnas kvar efter avverkning för att manipuleras så att de snabbare blir döda träunderlag. Då slipper man också tunga skogsmaskiner med stubbrytare som använder stora mängder energi för att utvinna dessa resurser för att producera energi och växthusgaser medan världen vill bli koldioxidneutral 2050. Biodiversitet påverkas också av stubbutvinning. För att påskynda nedbrytningen av trädstubbar kan det vara intressant att experimentera med olika typer av organiskt gödselmedel som läggs på stubbarna som manuellt har manipulerats. Nackdelen med att påskynda nedbrytning av död ved är att dött virke innehåller stora mängder kol som också släpps ut snabbare. Detta kan göra manipulationsmetoden för trädstubbar endast tillämplig på mindre hyggen.

Intressant nog, från det faktum att stubbar som har skapats genom manuell avverkning innehåller mer insekter, kan man dra slutsatsen att dessa stubbar efterliknar en stubbe som skapas av naturliga störningar. Eftersom dr Webjörn försöker förbättra det tråkiga utseendet på tidigare avverkningsytor i sin skog genom att skapa naturliga störningar, återställer han också möjligheterna till en mängd olika arter som är beroende av död ved genom att få stubbar att se ut som om de orsakats naturligt störda influenser. Sammanfattningsvis visar inte statistiken att den föreslagna manipuleringsmetoden påskyndar nedbrytningsprocesserna i trädstubbar. Inga solida bevis kunde ses som bevisar att denna metod faktiskt fungerar men det verkar finnas tecken på att det kan ha en viss inverkan på somliga trädslag. Statistiken visar dock att manipulation har en gynnsam inverkan på biologisk mångfald. För att få tydligare resultat krävs en bättre organiserad framtida forskning för att studera metoden för manipulation av trädstubbar.

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Figure 3. *Schematic depiction of examples of manual manipulated tree stumps: A convex bowl shape (A), randomly cut slits (B), randomly cut out shapes to mimic a more natural disturbance (C).* [Illustration by Thomas Leonard Reneman, 2021]

Figure 4. *Location of Römora where the field research areas are situated. Lantmäteriet/OptiWay AB 2021.* [Eniro, Lantmäteriet/optiway, 2021]

Figure 5. *This image shows the metal probe and measuring tape that has been used to document all the tree stumps.* [Photograph by Thomas Leonard Reneman, 2021]

Figure 6. *Schematic depiction of tree stumps that have been manually created by using a chainsaw, have remaining felling hinges and uneven surfaces after manual felling (A), and tree stumps that have been mechanically created by a harvester cutting head are usually lower and have flat surfaces after machine felling (B).* [Illustration by Thomas Leonard Reneman, 2021]

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Figure 8. *Examples of insect traces in European aspen (A) and European white birch (B).* [Photograph by Thomas Leonard Reneman, 2021]

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Figure 14. *Presence level of moss on manually created stumps with a basic hinge (H), manually created stumps with incisions (C, RC, and S) and mechanically created stumps with a flat surface (N). Crosses show mean values, the whiskers show spread of observations.* [Graph by Thomas Leonard Reneman, 2021]

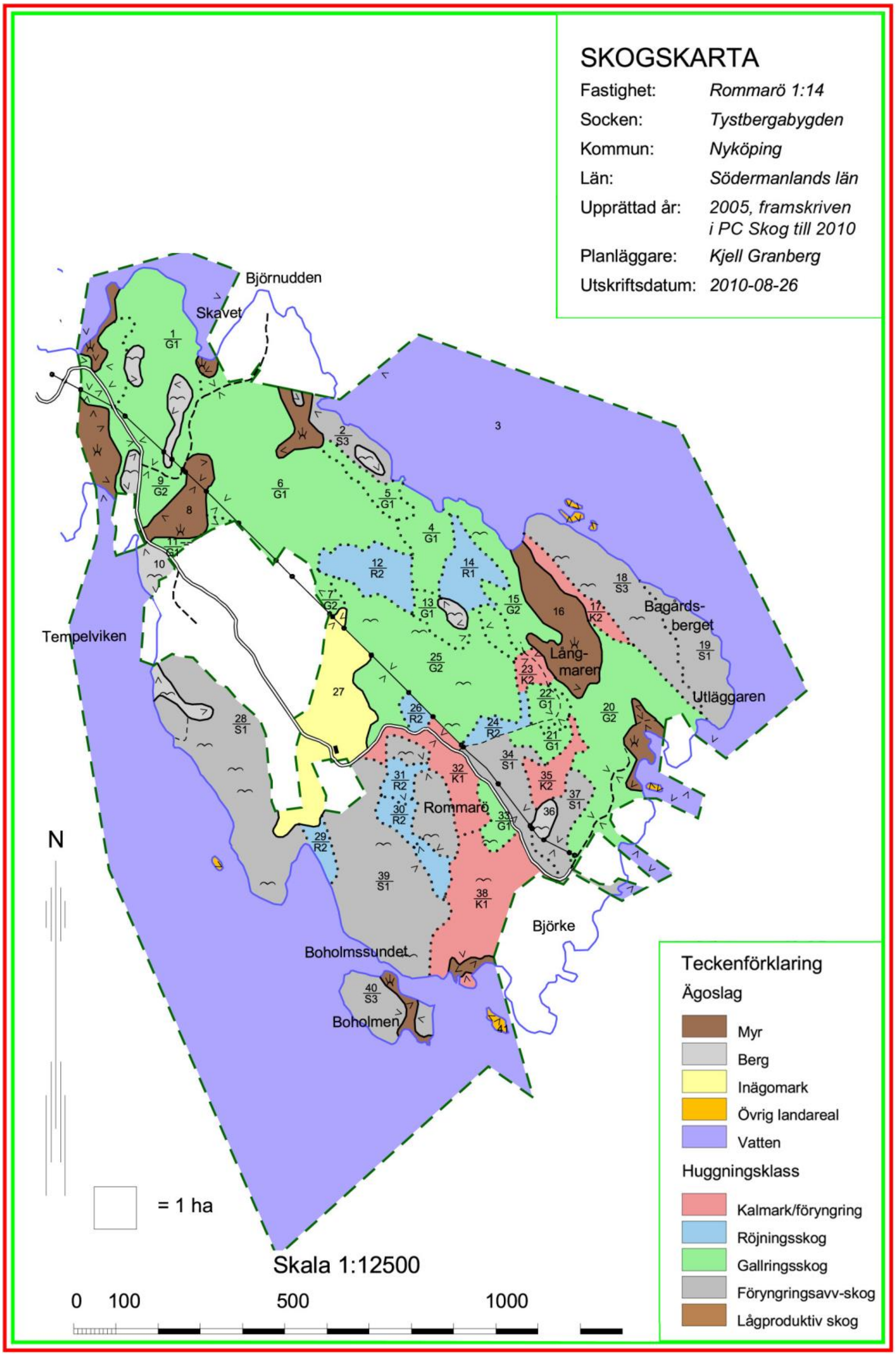
Figure 15. *Presence level of lichens on manually created stumps with a basic hinge (H), manually created stumps with incisions (C, RC, and S) and mechanically created stumps with a flat surface (N). Crosses show mean values, the whiskers show spread of observations.* [Graph by Thomas Leonard Reneman, 2021] by Thomas Leonard Reneman, 2021]

Figure 16. *Presence level of fungi on manually created stumps with a basic hinge (H), manually created stumps with incisions (C, RC, and S) and mechanically created stumps with a flat surface (N). Crosses show mean values, the whiskers show spread of observations.* [Graph by Thomas Leonard Reneman, 2021]

Figure 17. *Presence level of insects on manually created stumps with a basic hinge (H), manually created stumps with incisions (C, RC, and S) and mechanically created stumps with a flat surface (N). Crosses show mean values, the whiskers show spread of observations.* [Graph by Thomas Leonard Reneman, 2021]

Figure 18. *Schematic depiction of a Stump created by natural disturbances (A), a stump created by manual felling (B), a stump created mechanically (C).* [Illustration by Thomas Leonard Reneman, 2021]

8. APPENDIX



Source: *dr Jonas Webjörn, 2021.*